U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Workforce Development for the U.S. Wind Industry

Review Draft

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Executive Summary

Wind energy, like any element of the power system, requires skilled individuals to ensure that it is implemented and operated in a safe, affordable, and reliable manner. Skilled individuals are needed in all industry sectors, from engineering to business, construction to management, technical operations support to biology, and accounting to resource assessment. Without skilled people, the wind industry cannot grow or even maintain current operations.

As described in the *20% Wind Energy by 2030* report, the wind industry may require a potential workforce of 200,000 people by the year 2030, compared to 85,000 current wind-related jobs (1). Even in today's depressed economic market, companies are struggling to find individuals with experience in wind technologies.

The Obama administration also recognizes that U.S. job growth and a green economy based on a highly skilled workforce are high priorities. This understanding has helped to lead an effort to support a lifelong commitment to education development in the United States.

This document outlines a roadmap for comprehensive workforce development in the U.S. wind industry. This roadmap:

- Describes the current state of the wind energy workforce
- Describes the educational needs and skill sets defined by the wind industry
- Provides insight into the current status of wind education institutions at all levels
- Describes some of the key findings of meetings with educators and wind industry representatives on the challenges of implementing an educational framework to support the wind industry
- Provides initial recommendations on projects and activities to support the expanded development of a wind workforce.

Staff at the National Renewable Energy Laboratory (NREL) developed this workforce development roadmap in collaboration with staff from the U.S. Department of Energy's (DOE's) Wind and Water Power Program and the American Wind Energy Association (AWEA). DOE's Wind and Water Power Program provided direct support for this project. This document intentionally does not specify who should lead or take part in any of the activities or provide development details. It simply describes a series of activities that could be used to address the challenges identified in the wind workforce sector.

Activities in the following areas are recommended to support wind workforce development:

National workforce development

- Expand wind energy skills analysis to better understand the skills needed by the industry, obtain a better estimate of expended workforce needs, and better define the existing infrastructure
- Develop a cross-disciplinary advisory group and support structure to help direct and coordinate activities
- Develop teacher-training and support programs to train and keep educators current on the changing wind market
- Support the development of wind energy educational programs at all levels

(1) According to the American Wind Energy Association.

- Expand university, industry, and community college collaboration programs.

Primary and secondary education systems

- Implement K-12 wind energy education programs to expand the pipeline of students interested in wind energy and sciences
- Expand K-12 teacher training programs to provide resources to teachers interested in wind technology
- Expand efforts to coordinate and support K-12 curricula development
- Expand the implementation of turbines at schools so that students and communities get a firsthand view of wind technology
- Spotlight programs, opportunities, and successes to expand the understanding of wind technologies
- Implement state and national wind competitions
- Develop secondary school vocational training programs to allow students to rapidly enter the wind workforce.

Community college, vocational, and direct organizational training centers

- Standardize curricula development so that industry members know what recent graduates know
- Develop secondary and non-traditional vocational training programs
- Create and support a community college Web portal so that interested students and industry members know where to find good programs
- Support wind energy infrastructure development at community colleges and other vocational training programs
- Develop a program to recruit, train, and maintain the skills of wind energy instructors
- Develop coordinated educational pathways for students to expand their skills throughout their work lives.

Higher education

- Identify skills required to expand the wind industry (not only in science and engineering but also in all wind-related fields)
- Support a national information clearinghouse for university programs to link students to programs and the industry
- Expand Wind for Schools and other wind program development activities
- Support industry-university collaboration to expand internships, scholarships, fellowships, postdoctoral appointments, endowed professorships, and research
- Launch university-level national wind competitions
- Develop a university collaboratory (or consortium) similar to the European Wind Energy Academy.

An industry survey conducted by the American Wind Energy Association determined that in today's market, more than 50% of the new hires do not have the skills required to perform expected duties. Without a strong program to support wind workforce development, on-the-job training will result. Several potential impacts are likely if staffing growth in the wind industry is primarily achieved by hiring people without firsthand experience in wind energy from other fields:

- Reduced project performance levels due to poor siting and assessment

- Decreased turbine reliability/availability levels due to poor maintenance
- Increased risk and associated insurance for technicians and other service staff
- More difficult-to-site installations caused by sloppy or poor project development and installation
- Reduced technology development due to a lack of knowledgeable engineers and scientists working in turbine development.

To achieve the vision of 20% of the nation's energy from wind technology, over the next 15 years the wind industry must transform from a niche market to one of the nation's mainstream power generation technologies. Such a change has not occurred in the power sector for more than 40 years, since the rapid expansion of the nuclear industry in the 1960s and 1970s. As described in the *20% Wind Energy by 2030* report, this shift is possible, but it will not occur without talented and educated people. This document outlines a potential path to developing human capital.

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Introduction and Statement of Issues

As described in the *20% Wind Energy by 2030* report (2), there are many benefits to supplying 20% of the nation's electrical energy from wind technology. The Obama administration also recognizes that U.S. job growth and a green economy based on a highly skilled workforce are high priorities.

Achieving these priorities requires developing the workforce of today and tomorrow. The analysis conducted as part of the *20% Wind Energy by 2030* report calls for approximately 500,000 new jobs related to the wind industry by the year 2030. Approximately 200,000 of these positions will require understanding of wind technologies. Even in today's depressed economic market, companies are struggling to find individuals with experience in wind technologies.

Based on assumptions identified in the *20% Wind Energy by 2030* report and current market trends for the near-term installation of wind technology, the ongoing job needs (3) are:

- 47,000 construction jobs
- 22,346 manufacturing jobs
- 3,580 other jobs related to construction
- 66,035 related indirect jobs (additional skilled people who require an understanding of wind technologies as it relates to their fields; e.g., bankers, lawyers, and engineers).

In 2008, the U.S. wind industry installed approximately 8.4 gigawatts (GW) and employed an estimated 85,000 people. Using these initial figures, two potential estimates for expanded industry growth range from the need for an additional 85,000 people to allow a doubling of the current installed capacity to approximately 54,000 new people to support the difference between the current workforce and that identified in the *20% Wind Energy by 2030* report. To maintain the schedule described in the report, these workforce additions are required over the next 5 years.

In 2009, almost 10 GW of wind were installed in a depressed economic market, further demonstrating that an annual installation capacity of 16 GW by late in this decade is definitely achievable under normal economic conditions.

Long-Term Training Requirements

Estimates of long-term training needs are difficult to determine. Increasing existing staff numbers will be required to support the approximate doubling of annual capacity installations. The expansion of wind component and system manufacturing in the United States (with a goal to increase U.S. content of wind systems to 75%) and attrition of the existing workforce will play a role in determining the number of newly trained staff members needed annually. These scenarios must also be examined in the larger context of the public power sector and increasing needs for technical skills nationwide. As an example,

(2) The *20% Wind Energy by 2030* report is the first and only document that considers a projected growth for the wind industry consistent with current market trends and then describes the expected impacts and challenges to meeting such an implementation path. This document also represents a consensus assessment of the growth potential. Other projections of wind industry growth have been conducted, most notably the DOE Energy Information Agency's Annual Energy Outlook, but this document only considers current government policy and as such has historically underestimated wind sector growth. Although some might see the *20% Wind Energy by 2030* report as an upper limit of the projected wind installations, it is in fact tracking well below current industry trends, which would indicate it may be an appropriate benchmark for at least the near term.

(3) Assuming approximately 16 gigawatts of installed capacity per year.

the Center for Energy Workforce Development estimates that approximately 46% of all engineering jobs in the utility sector could be vacant by 2012 due to retirements by the aging workforce and other forms of attrition. The 20% Wind Energy by 2030 indicate that approximately 1,000 new wind technicians will be needed each year by 2014, expanding to 1,400 technicians per year in 2016 when an estimated 16 GW of capacity is being implemented annually.

A recently completed AWEA industry survey identified near and mid-term staffing needs for the wind industry (4). It should be noted that this information collected for this survey was conducted before anyone realized the true impact of the current economic downturn, so the categories should reflect near-term hiring needs for a robust wind market. This survey also only represents the portion of the industry that responded to the survey, so these categories should be considered in that light. This survey identified that the following positions as those that are most needed in the near to medium term:

- Accountants
- Electrical and mechanical engineers
- Business development and project managers
- Wind technicians.

In a Texas Technical University report (5), researchers estimated that based on employment estimates from the 20% report, approximately 1,000 professionally trained (bachelor's degrees or higher) individuals would be needed per year to support the capacity installation levels outlined in the 20% by 2030 report. Based on the AWEA survey of workforce needs, the following job types requiring an advanced degree are most needed in the near term:

- Manufacturing engineer
- Material engineer
- Account manager
- Project manager
- Mechanical engineer
- Electrical engineer
- Engineering manager
- Construction manager
- Development director
- Business development manager.

An additional estimate for the training needs is based on information gained by looking at current wind installations around the country. These indicate that the staffing requirements for new plant operations (positions created whenever a new plant comes online, assuming 16 GW of new capacity per year) would be:

- 1,000 to 1,600 new plant operators
- 3,700 to 4,800 new personnel in induced markets, some requiring wind experience.

Assuming an increase in the market capacity from approximately 7.5 GW to 16 GW per year by 2015, this

(4) A summary of this data has not been released although some data has been provided in general presentations. AWEA plans to report on these survey results in 2010.
(5) Swift, Andrew, & Walker, Richard (2009). *Filling the Wind Industry's Critical Need for Professionals Educated in Wind Energy*, Poster at 2009 Windpower Conference and Exhibition, Chicago, IL - May 4 - 7, 2009.

will require training an additional 15,000 workers per year just to reach the expected installations described in the *20% Wind Energy by 2030* report.

Educational System Development

States such as Colorado, South Dakota, Nevada, and Montana have supported the training of engineers and other experts for the oil, natural gas, and coal industries. A private organization started the Colorado School of Mines in 1866. It became a territorial institution and then finally a Colorado state institution in 1876 when Colorado attained statehood, demonstrating Colorado's 100-year commitment to educating students for the mining industry (6). From the federal perspective, in the 2009 fiscal year DOE provided more than $9.2 million for university educational infrastructure and student-focused support on nuclear technologies, in addition to a well-funded, university-based R&D portfolio ($44 million over 3 years) and sponsored conferences, Web sites, and curricula development to ensure a steady stream of engineers and scientists entering the nuclear field (7). Although many universities and community colleges are developing new education and training programs focused on wind technologies, no federal infrastructure currently exists for the wind industry.

Although there is a clear short-term need for wind energy technical experts and individuals who can deploy and maintain wind projects, developing long-term educational paths such as those in other major energy sectors is also needed. These long-term paths not only guarantee the workers needed to fulfill the industry's current needs but also ensure continued improvement and expansion 10 and 20 years from now. This includes developing continuity among all levels of the educational sector, training teachers and professors to expand the knowledge base, and developing paths to allow individuals currently in related fields to obtain the expertise they will need to support the wind energy industry. It is also important to note that there is a time element in implementing educational pathways as it can take a minimum of 8 to 10 years to provide the training and experience for a professor to teach classes in a specific technical field. As the industry and number of programs grow, simply training the trainers represents a long-term commitment.

Although the existing pathways used to support other energy technologies should be leveraged, the different roles and education focus of the wind industry must be more clearly defined. Outlining these potential education development pathways for wind energy is one of the key elements of this document.

Desired Outcomes

The following are the desired outcomes of a successful workforce development program:

- Availability of individuals with the required training, skills, and experience to support the current and potential expansion of the wind industry
- Immediate training opportunities available to existing staff in the wind industry
- Enhanced and sustainable energy education that maps to the green energy economy
- Defined pathways from primary schools through the post-graduate level and into industry
- Standardized curricula and certification for key jobs as needed
- Development of trained instructors and continuing education of instructors at all levels of the educational system

(6) Colorado School of Mines Web site, http://www.mines.edu/History, accessed April 13, 2010.
(7) U.S. DOE Nuclear Energy Universities Programs Web site, http://www.ne.doe.gov/universityPrograms/neUniversity2a.html, accessed April 13, 2010.

- Expanded inclusion of women and minorities into the wind industry
- Active engagement of all of the educational sectors, including trade unions, student groups, apprenticeship programs, and industry-based training programs.

Stakeholders/Constituencies/Participants

Stakeholders representing many sectors are involved in the wind industry workforce development process, including:

- The wind industry, which includes turbine manufactures, project developers, project support organizations and consultants, component suppliers, and other associated support industries
- The educational industry, representing universities, community colleges, vocational training institutions, other professional or labor-training organizations, informal educators (such as research centers and museums), and K-12 schools
- Wind industry support organizations with educational mandates, such as AWEA and the American Council on Renewable Energy
- Federal and state sectors, including energy, education, and labor.

Appendix A provides an incomplete list of stakeholders. A graphical interpretation of educational pathways and how these different organizations intersect is provided in Figure 1.

The interest in wind workforce development from these organizations, especially in light of the Obama administration's desires to expand activities in this market as part of the national economic stimulus, indicates a need to provide cross-sectoral communication while not limiting individual sectoral development that does not require assistance. As we have already seen, this lack of coordination leads to redundancy and more market fragmentation, leading to higher-cost but lower-impact projects.

Without an overriding planning and coordinating body at the national and sectoral levels, redundancy in efforts and inefficient development activities are likely wasting time and limited resources. This roadmap acts as a guide to this shared endeavor by collecting robust ideas from the different constituent groups focused on developing a wind energy workforce.

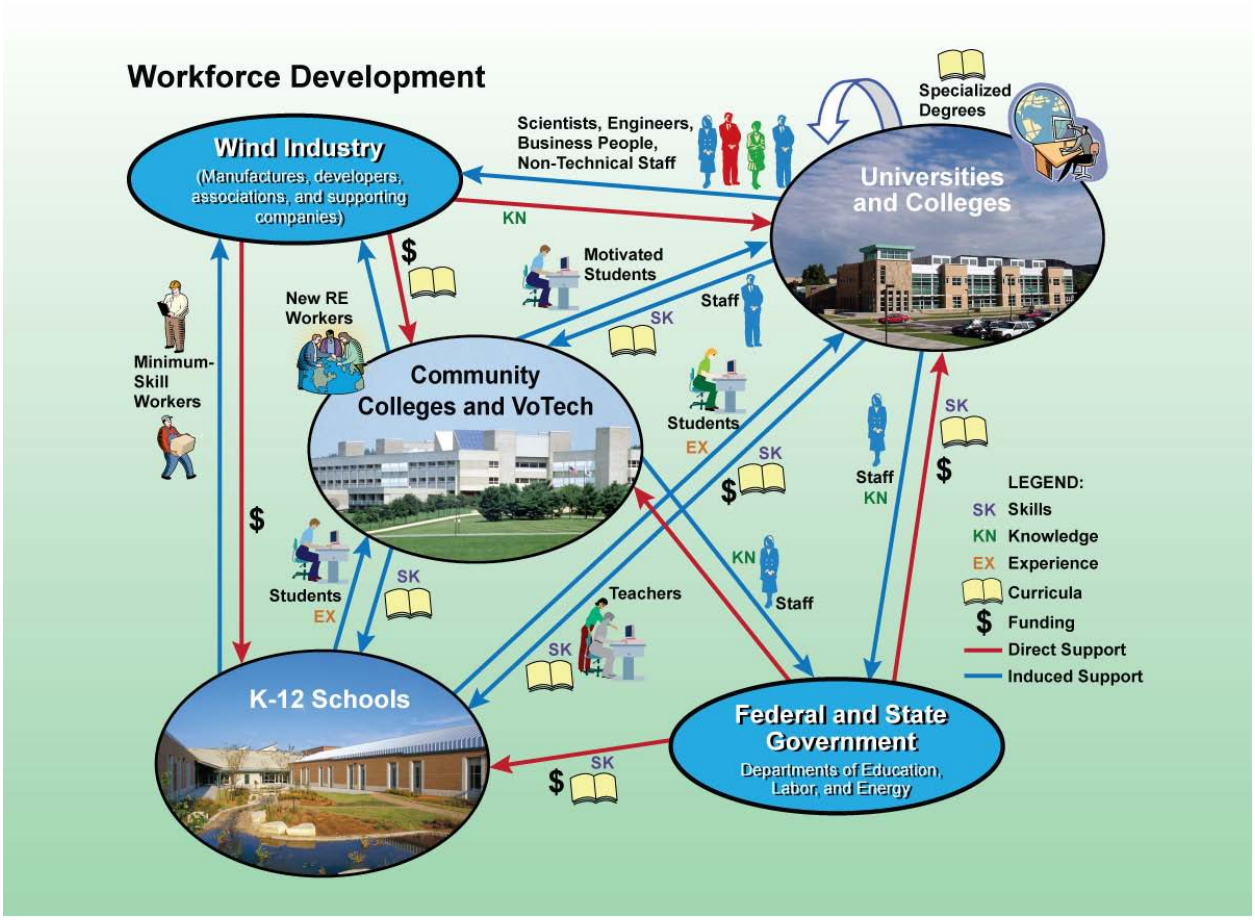

Figure 1: Workforce development and organizational pathways.

Wind Energy Workforce Needs

As with every energy technology, there is a need for a wide variety of professions and thus training programs to meet these needs. Specific personnel needs identified by the industry include:

Windsmiths: plant maintenance and local operators	Current needs are addressed by a general collaboration between community colleges and industry. Less than 1 year of educational and apprentice training is typically required. Specific fields are addressed through on-the-job training.
Operations, maintenance, and middle-management professionals: facility and manufacturing managers, accountants	There professionals are currently needed to support wind plant development, operations, and manufacturing. One to 2 years of classes or on-the-job training based on a solid educational foundation are typically required. AWEA is conducting area-specific workshops.
Construction, implementation, manufacturing, and electrical system experts: construction workers, surveyors, crane	The current need is typically met by utilizing existing technical trade groups with limited wind-specific training. Limited re-training through specific programs is required, although there is a need for personnel with experience in skilled crafts, quality assurance, quality control,

specialists, electricians, and linesmen	and wind turbine commissioning.
Business experts: experts in law, banking, insurance, management	Training to meet current needs is based heavily on existing educational programs. Requirements include initial wind-focused short courses and more detailed secondary training with up to 1 year of development time. AWEA is conducting area-specific workshops, and on-the-job training enhances the knowledge based on related professions.
Engineering experts: civil, electrical, power, manufacturing, mechanical, materials, and transmission engineers	These professionals are currently needed; 2 to 4 years of development time are required. Skills are generally based on basic engineering knowledge from related professions or academics, but an understanding of wind technologies and wind-specific experience is required.
Other wind applications experts: biology scientists and experts in land use, the global supply chain, business, and resource assessment	These experts are currently needed to support many critical roles in wind assessment and appropriate development. One to 3 years are required to develop skills, and training is usually based in larger diverse programs with identified specification. The current focus is on employing individuals with the appropriate background but without prior wind experience or through limited job-based or external training.
Research experts: scientists and research engineers with advanced degrees for expanded technology development	There is less of a current need for experts in this area, but these positions will be critical to continued reductions in the relative cost of wind energy and an expanded understanding of wind energy systems. These individuals will also be the linchpin in the higher-education development process, training the next generation of wind implementers and scientists. The development of expertise at this level requires 4 to 8 years, and there is limited systematic developed infrastructure to date.

In many instances, these fields require strong science and engineering backgrounds, combined with an interest in renewable energy. Due to the current K-12 educational system, an interest in technologies needs to be instilled in students at the K-12 level (with a focus on high/secondary schools) so that they will have the skills and interest to enter the wind energy workforce. Current education curricula practices direct students as early as the 6th grade to select a general academic focus, which means that wind- and energy-focused development activities must begin prior to that threshold.

Additionally, renewable technologies research and implementation fields are not currently racially and socially diverse. As indicated previously, according to the National Science Board the only populations expecting expanded graduation rates in the science and engineering fields are women and minority populations (8). Green jobs and green industry must represent the entire nation in order to be accepted by everyone. Expanding outreach and workforce education to enlist all social and racial sectors will be critical to long-term wind industry success.

(8) National Science Board, *The Science and Engineering Workforce – Realizing America's Potential*, National Science Foundation, (2003).

Current Status of Wind Workforce Development Activities

Many efforts are underway to support and expand wind industry workforce development options and to better understand the wind industry's workforce development needs. Various industry group and educational organizations have already implemented workforce development programs. Activities are also supported by DOE's Wind and Water Power Program, NREL, AWEA, the U.S. Department of Labor (DOL), and the National Science Foundation (NSF). Many state-based programs are also underway. A summary of these activities is provided in Appendix B.

Although expansion of the educational infrastructure is needed to meet the installation demand described in the *20% Wind Energy by 2030* report, a strong wind energy educational base on which to build already exists. The education system can be divided into three sectors: primary and secondary education (K-12); community college, vocational, and direct organizational training; and colleges and universities (see Figure 1).

Wind energy educational programs currently exist in all three sectors. See Appendix A and the AWEA Educational Programs Database for partial lists of these programs.

Primary and Secondary Educational Programs

Factors affecting the nation's ability to create a green workforce for the future include the lack of energy literacy (with wind and other renewable technologies being a further categorization); the lack of students entering the energy, engineering, and science fields; and a lack of science teachers. This deficit of support for science in the classroom is at the heart of several national activities and has been underscored by recent presidential releases from the Office of Science and Technology. The American Competitiveness Initiative is an effort implemented by the Bush Administration to focus support on expanding science and engineering educational opportunities. Additionally, discussions with K-12 educators indicate that most students are directed into general fields as early as 6th grade. Research also indicates that if minorities and women do not receive a positive introduction to technical fields by 8th grade, they are not likely to pursue careers in these fields.

Although generally limited, several types of wind energy educational programs currently exist. National standards-based curricula at several levels have been developed, including those from the NEED Project, KidWind, 4-H, and Energy for Educators. Several advanced curricula programs also exist at the state level, including the WindWise curricula (funded by the New York State Energy Research and Development Authority). Most of these programs incorporate hands-on teaching materials and structured teacher-training programs, generally funded through industry, state, or federal grants. Several states (including Michigan, Wisconsin, and New York) have developed implementation programs for wind turbines and curricula at K-12 schools. These programs help support the wider adoption of wind energy understanding within the communities and form the basis of hands-on living laboratories designed to spur interest in science and math at the K-12 level.

The DOE's Wind for Schools project works to address similar issues on a national basis, focusing on states with high wind potential and interest in expanded wind implementation. Many businesses, industries, and associations have developed wind-based educational activities that can be as simple as coloring books and as involved as the “Wind with Miller” series created by the Danish Wind Industry Association. In many cases, individual programs are not coordinated and are developed out of specific need with little cross-fertilization.

Another area that has not been fully explored is the K-12 vocational programs. These programs, many of which are supported through DOL formula funding, provide educational opportunities for high school or returning students. These programs provide a first level of job training, either as a precursor to community college or as entry-level technical positions.

Many state, regional, and national programs exist to support the expanded engagement in science and math, including Science, Technology, Engineering, and Mathematics (STEM) programs and Mathematics, Engineering, Science Achievement (MESA). Although not focused on wind technologies, they provide a strong leveraging opportunity for wind-related curricula. Wind-specific programs, information, and funding for K-12 education is scarce, partially due to the local nature of school funding and programmatic direction. With the exception of vocational programs and national activities such as the DOE's Wind for Schools project, most K-12 program support is provided by interested states or, to a limited degree, the local wind industry. An additional factor is that due to state and federal testing standards, it has become more complicated for schools to expand educational outreach. However, with curricula related to these standards, wind technologies provide a good opportunity to apply hands-on science, engineering, and math principles in the classroom that enforce the standards and also interest students. The wind industry also understands that introducing technologies at the community level works to expand technology acceptance, so there is a strong desire by industry to assist in the implementation of wind activities at community schools.

Community College, Vocational, and Direct Organizational Training

This category covers educational opportunities for core skills through traditional and non-traditional education sources. Activities range from short courses with specific technical focus to 2-year programs and apprenticeships. Except for community college programs, many of these offerings arise from a defined local need or champion who develops a program primarily based on local or personal interest. Except for AWEA's professional workshops, there are no cases of national organizations providing educational opportunities in the wind sector. Additionally, as the wind industry develops, several professional conference organizations are starting to notice the potential of the wind industry and are expanding their core offerings; however, these are typically general or focus on a specific region or market segment. The content, relevance, and value of many of these educational opportunities are debatable.

Many community colleges have introduced wind energy programs to meet the exploding need for skilled wind technicians. These programs typically build on a strong base of mechanical and electrical systems curricula. Several well-respected wind programs have operated for years and have provided the basis for much of the existing curricula and collaboration within the community college sector. A strong collaboration that includes representation from industry and community colleges supports the development of wind technologies curricula. Since most colleges have a strong local or regional educational focus, there is little concern regarding sharing curricula between new and older programs. Through close collaboration with community college programs and the wind industry, AWEA is in the process of describing the core skill requirements for a wind technician and plans to develop a certification process for educational programs. There has been discussion regarding expanding this technician definition to include advanced wind technicians or specific skills relating to systems that require deeper understanding, such as turbine blades.

State or local governments provide a majority of the funding for programs in this category. Many of these programs also receive funding or equipment support from the wind industry. According to AWEA's survey, of the 78 educational institutions responding, 45 of these had received support from the wind industry and industry-supported educational programs, and 65% were community colleges, technical, and vocational schools. In most cases, however, the primary funding source for these programs is tuition and lab fees.

Through funding provided by the American Relief and Recovery Act, the DOL provided several funding opportunities for clean energy educational programs, especially job training programs. Through these grant opportunities, generally combined under the title of the Green Job Training Grants (9), 18 grants specified wind energy activities. Information on these grant solicitations can be found from the DOL press releases for the grant awards (10).

College and University Programs

As the wind energy market expands, university and 4-year college programs are more prevalent. Due to the relatively new nature of most of these programs, they tend to be informal, providing one or two classes but no recognized accreditation or minor. In many cases, these programs are built around one or two faculty members who work in the area, supported by research or general interest. Graduates have knowledge gained primarily through research projects as compared to class-based education. A small number of universities and colleges provide a defined wind-based curricula, resulting in a certificate or minor in the area of wind technologies, although this is beginning to change. In almost all cases, master's-level or PhD work is also research-based and does not provide degrees in wind technologies. It is likely that in the future, a wind energy program will be developed that allows advanced degrees with wind-specific titles, as is common in other industries.

In almost all cases, the existing programs are in the engineering area (typically mechanical, industrial, or electrical). Few programs focus on non-engineering disciplines, such as biology or business, or more specific engineering skills, such as supply chain or transportation.

In most cases, the existing programs provide a basic curricula and only provide a specific technical focus by default of their location or the specialty of the school or a principal professor (such is the focus on offshore wind technologies found in schools in the northeast maritime). The expansion of the wind industry is starting to attract the attention of higher-education administrators, leading to more defined programs within some universities and colleges.

Funding for these programs is largely provided through task-specific research and, more recently, competitive solicitations from the DOE and through the Wind for Schools project. In some cases, state organizations provide funding; however, in most cases, this flows from the interest of a specific professor and not by some direction at the state level. There is currently no collaborative effort to develop a national university consortia, such as the European Academy of Wind Energy effort (11). The academy is a consortium of European universities that provide an education and research collaboration in the wind energy field. The NSF is considering applications for the development of an

(9) U.S. Department of Labor, Green Job Training Grants 2009. Referenced April 16, 2010. http://greenjobtraininggrants.workforce3one.org/.
(10) Referenced April 16, 2010: http://www.dol.gov/recovery/MoreAnnouncements.htm.
(11) European Academy of Wind Energy, http://www.eawe.eu/.

industry/university collaborative research center, which could form the basis of such collaboration. Industry also provides some funding; however, due to many factors it lacks the robustness of other energy sectors.

Identification of Educational Needs for Wind Energy Workforce Development

Through the DOE Wind and Water Power Program's workforce development activities, NREL staff in collaboration with the AWEA Education Working Group have held several public meetings to focus attention on the wind workforce development issue. These meetings, combined with the expanded discussions as part of the AWEA Education Working Group, have included representatives of industry, educational institutions at all levels, state and federal government organizations, and other interested parties. These meetings have resulted in a better understanding of developing a trained wind workforce.

The critical factors identified through the collaborative discussion that addresses the workforce development process include the following:

- *Pathway development.* A full systems approach for educational pathways is required, starting with students in primary and secondary schools and leading through community college, bachelor's programs, and into post-graduate education, with appropriate offramps into industry and onramps for returning students.
- *Teacher-training programs.* Wind technology is a new industry, and there are a limited number of individuals (inside and outside of the educational field) who can provide quality instruction. A large effort is required to provide support for and the development of teachers and teacher-training programs at all levels.
- *Program development support.* Most educational programs at all levels are developed through leveraged and/or unfunded activities at new or existing educational organizations. Resources to help develop programs, either conceptually or physically, will greatly ease and speed up the development process.
- *Expanded coordination.* National-level coordination among the different market sectors will be important to guarantee that a coordinated educational infrastructure is implemented, reducing pragmatic overlap and the lead time to implement programs while ensuring industry participation and support.
- *Better understanding of available and required elements.* The industry requires a good assessment of existing program, activities, and curricula in addition to a better understanding of workforce needs and task requirements at all levels.

Through these discussions, wind industry members identified the following educational needs, which clearly overlap with concepts expressed by other sectors:

- Development of better or better-defined career ladders, pathways, and training programs directed at industry, understanding that many field sites are in remote areas where training opportunities are limited
- Better standards and skill categorization to understand which skills are needed for different personnel and job types

    - Wind technician standards (currently underway at a basic skills level identifying minimal standards for safety and technology understanding)
    - Students for internship programs
    - Educational support expanded to all other business areas.
- Stronger alignment with academia at all levels.

In addition to the above, discussions were also divided among the three common educational sectors introduced above, providing the following list of concerns and considerations to wind education development and expansion in their sectors.

Primary and Secondary Educational Systems

- Address the need for better understanding and marketing of existing curricula and materials, including more ways to distribute curricula to the public. Some curricula already exist, but visibility is limited, and budgets for training and outreach are difficult to obtain.
- Address wind industry engagement to encourage adoption and implementation of K-12 wind-related materials in areas of interest
- Expand collection of and provision of technical review of existing and planned curricula, including a gap analysis to determine necessary additional curricula development
- Provide support to expand curricula options
- Expand turbine implementation at schools through defined programs such as the DOE Wind for Schools project, partly to address safety issues with "do it yourself" or untested turbines that can create problems, create safety concerns, and potentially damage industry perception
- Spotlight success stories for projects, opportunities, career paths, and programs that work
- Implement wind energy competitions to entice students into engineering and sciences
- Address the lack of methods to bring people from the industry into the educational system, either as part of train-the-trainer activities, to teach classes, or as a means to interest students in the wind sector
- Coordinate programming and opportunities, either through AWEA or another national coordination body
- Provide case studies and examples of pathways (types of jobs) into the industry for use by academic counselors
- Provide group-specific support directed at young women and minorities, sparking interest in wind and science fields at an early age
- Address lack of vocational and preparatory programs at the secondary level (prepping new or returning students with the skills and prerequisite requirements to enter industry or the community college system).

Community College, Vocational, and Direct Organizational Training

- Define additional training needs, identify critical skills, and develop course outlines/offerings for other specialty skills of a technical and non-technical nature. Offerings would include specialized

technician skills such as blade maintenance and advanced tower rescue but would also include curricula development, such as a 100-hour introduction seminar for people enhancing existing technical or non-technical skills (such as engineering, project management, accounting, and siting). This should include the development of needs-based standards for each of the courses identified

- Formalize a process to identify technical and community colleges with an interest or focus in wind energy
- Support program development in the following areas:
    - Grants to support the purchase of expensive equipment, including an inventory of used or damaged equipment available to community colleges
    - Grants to support general costs of starting new and expanding programs, providing a bridge until the programs can become self-sustaining
    - Apprenticeship/internship programs for students at industry and national laboratories, including standards and requirements, an internship database, and a Web portal.
- Support expanded training opportunities for teachers and staff:
    - Distance learning opportunities, technologies, and curricula
    - Executive loan program to bring industry and laboratory experience into the classroom
    - Video recordings of industry and laboratory professionals, wind systems, and components for use at multiple class levels
    - Professional development funding and opportunities for teachers/professions, including internships with industry and research centers.
- Support cross-fertilization among organizations so that new programs won't have to reinvent the wheel and older programs will have better access to resources (grant writing, equipment availability, etc.)
- Provide better documentation of the programs' impacts and achievements
- Consider better coordination with 4-year schools (feed-in and credit acceptance) and K-12 outreach and community college preparatory organizations. Many students graduating from K-12 do not have the math skills needed for wind tech programs
- Support active industry job development via industry green workforce integration/job placement programs/job networking activities to ensure quick placement of graduates.

College and University Programs

- Better define needed general skills, specific knowledge, and ways people enter the industry, specifically in engineering, business, management, and cross-training
- Support the development of educational programs, especially in states without established wind interest/support
    - Develop programs by incentivizing the initiation of wind programs, likely through the engagement of new or junior faculty
    - Develop and incorporate curricula by building from existing material in all appropriate fields (offshore, onshore, engineering, capstone, business, environmental, etc.), including similar non-wind-specific curricula

- Implement challenges and competitions to foster idea generation and build interest in wind energy
- Develop a university consortia to allow stronger university-to-university collaboration, curricula sharing, and student exchange, similar to the European Wind Energy Academy. This organization could also lead the development of a coordination group to allow certification of wind programs at higher levels
- Develop better collaboration among universities and industry (including with Europe) to allow:
    - Teacher training/faculty activities to ensure learning on the current technology and underlying theory
    - Internship and co-op opportunities at industry and laboratories
    - A mechanism to link potential employees with employers.

Recommendations

Significantly expanded wind energy development is not a matter of whether; it is a matter of when. Given all of wind energy's positive drivers (low cost, secure resource, domestic development, low environmental impact, no carbon emissions, low water use, and low capital risk), the wind industry will have a strong role in future energy development. Even during the heart of the economic downturn, in 2009 the wind industry installed almost 10 GW of capacity due to a strong pipeline of projects that could move forward in the depressed economic market. The current market, although painful to many, may actually give the industry some breathing room and allow it to develop at a healthier rate.

This slowing of the wind industry will provide educational institutions a chance to catch up and develop programs that will allow the industry to draw from a stronger talent pool once it again picks up steam. The following recommended actions will help support the development of this talent pool.

This document intentionally does not specify organizational leads for the activities outlined or provide details about that development. It simply describes a series of programs that could be used to address a number of the challenges identified by the specific interest groups, primarily the industry and educational sectors. As described previously, many educational development projects on the regional or national level are already underway and, where appropriate, these should be expanded.

During interviews and meetings, wind industry stakeholders and representatives from educational institutions of all levels and government identified the following activities as critical for the expanded development of the wind energy workforce.

National Workforce Development Coordination and Definition

The following list provides a foundation for the development of a national wind workforce development program by providing the analysis and coordination to insure that the efforts underway by the many different entities supporting these activities are focused to insure maximum impact. These activities include:

- *Expand wind energy skills analysis.* Although there is a general understanding of the need for expanded educational programs, little documentation exists (except for AWEA's initial industry survey and a few other reports) about the required skill sets and number of people needed. Further analysis is needed to better define the specific job numbers and associated critical skills

through a consolidated needs assessment and analysis. This activity would lead to the development of wind energy educational pathways as well as allow funding organizations to focus resources at the most critical skills.

- *Support cross-disciplinary advisory group and support structure.* Support the development and staffing of an organization and cross-disciplinary advisory group modeled on the National Wind Coordinating Committee. This organization would work with government, the wind industry, existing workforce development organizations, and the existing educational infrastructure to advise all organizations a wind energy workforce development program. This group would provide a means to facilitate dialog among educational sectors, industry, and laboratory stakeholders, expanding on the limited capabilities of the AWEA Education Working Group. As a subgroup or independent of the overall effort, a federal coordination group should be formed to allow more direct coordination of funding for wind activities to maximize the impact of the federal resources. Current activities at the federal level have thus far been completed in relative isolation.
- *Develop teacher-training and support programs.* Although a few teacher-training programs have been implemented, they cannot keep up with the needs of the educational institutions at all levels. Expanded internship and development programs for teacher training within industry and at national laboratories should be implemented. This should include activities for K-12 teachers (teacher-training workshops associated with state and federal science meetings), internships at all levels, wind-specific summer educator training programs, and continued development of curricula that can be provided to educators to support class activities.
- *Support wind energy program development.* The development of a new wind-focused educational program at any level is expensive and time consuming, especially at the community college and university levels. In many cases, once a program is operational it can sustain itself through independent grants and student tuition, so funds to support the development of these programs are critical. Many current grants are focused on deliverables, requiring specific products such as curricula or research, but are not geared toward implementing the institutional framework to initiate a new program. Grants to educational institutions or state organizations to support the development of wind-directed educational programs at all levels should be expanded.
- *Expand university, industry, and community college collaboration programs.* More efforts are needed to expand the collaboration among universities, community colleges, national laboratories, and industry in the areas of teacher training, training collaboration, and internship involvement. Some efforts exist to expand on active programs, such as DOE's Office of Science, Science Undergraduate Laboratory Internships, Community College Institute of Science and Technology, and the Pre-Service Teacher internship programs. These activities could also be expanded to open paid or co-funded internships with key industry partners, leading more directly to active workforce expansion. This activity would also expand the pool of interested and active educators in the academic industry and provide a means for expanded collaboration among industry, laboratories, and educational organizations. These activities would strengthen the university-industry bond, supporting new technology development, but also the graduation of many students through the support of industry into the educational sector, a support that is quite common in other, more highly institutionalized energy technologies.
- *Coordinate educational pathways.* Community colleges provide a bridge between high school and university or the industry. For this reason, community colleges attract students interested in advancing their skills, but at the same time develop pathways to allow universities to accept

students who wish to expand their skills beyond what the community college can provide. This process becomes more complicated since the wind industry and its educational needs are not universal; links between the local community college and the state university are only likely in states with robust wind markets. For this reason, organizations and community colleges must work harder to develop links with institutions of mutual interest. Clearly the development of industry standards and certification of college programs will support these links, but efforts are needed to bridge these gaps more effectively.

Development Needs of the Primary and Secondary Education Systems

As described previously, work at the primary and secondary levels not only introduces more people to the impacts and benefits of wind energy, but it also "primes the pump" of the wind energy workforce at all levels. The following activities support expanded wind energy understanding and interest at this level:

- *Implement K-12 wind energy education.* Expansion of existing standards-based curricula and wide-scale implementation through science teacher-training programs would assist in priming the pump for the green and expanded science-based workforce. Support for state or national teacher-training programs, including the provision of materials and advanced training support to allow in-class co-teaching opportunities, will increase the number of students interested in pursuing science and wind-based activities. Near-term efforts should be made to highlight existing curricula and support its implementation. This can happen initially through direct outreach to industry and through the development of mechanisms such as blanket grant applications to allow schools, states, and affinity or other interested organizations to apply for federal, state, or industry grants to support teacher training and curricula implementation. These activities could be used to better access existing funding opportunities in the near term.
- *Expand K-12 teacher training program*s. Develop, expand, and/or provide additional funding to existing programs targeting science teachers to engage them in research, such as the Pre-Service Teachers, the DOE Academics Creating Teacher Scientists, and STEM programs. These programs could be implemented at or through universities, industry, and at national laboratories and would expand the pool of interested and active K-12 science teachers.
- *Expand efforts to coordinate and support K-12 curricula.* Wind energy curricula at the K-12 level already exist; however, quality, accuracy, and effectiveness vary greatly. Curricula are also typically limited by the access to engineering and information sources, some of which is expensive to develop but could be used widely. A collaborative organization of individuals involved in K-12 wind- and science-based education should be formed to review and assess the current curricula in relation to national educational standards. This group would provide criteria for curricula development and a gap analysis of current curricula and recommend strategies for improving curricula while providing a clearinghouse for curricula development. In the near term, activities could focus on informing state, federal, and industry about high-quality existing criteria and the opportunities to work with educators to expand these resources, potentially allowing more state-specific activities.
- *Expand the implementation of turbines at schools.* Installing wind turbines at schools not only inspires students but also inspires communities to look at new energy technologies. As described earlier, inspiring students in science and engineering at a young age is a key element to directing students into these fields. Operating equipment that can be used in the classroom is one of the best ways to inspire. However, although new technology can provide this inspiration at the school and community levels, new technology that does not work or is not demonstrative of reality can in fact be counterproductive. For this reason, the implementation programs must be

coordinated, provide productive outreach with integrated resources, and demonstrate "proper" technology implementation. Coordinated and consolidated programs such as the DOE Wind for Schools project should be expanded to provide schools and states the ability to implement similar programs independently.

- *Spotlight programs, opportunities, and successes.* Limited information is available on successes and opportunities, such as career pathways, position descriptions, programmatic success stories, and general information to help K-12 schools and teachers educate students and community members about wind energy. An effort should be made to collect this information and make it available.
- *Implement state and national wind competitions.* Competitions from solar car races to robotic challenges have been used to spur interest in science and specific fields. Building on successful state and regional wind competitions such as the KidWind Challenge or the MESA wind turbine design competition, a national or regional wind challenge should be implemented for primary and secondary students. The challenge could culminate at a national wind event, such as the AWEA Windpower Conference and Exposition, which would cement the interest of students in wind technologies and provide strong networking opportunities. If funding could support a national program, states or schools could leverage local resources to support much of the activity cost.
- *Develop secondary school vocational training programs.* Secondary-level vocational programs are quite prevalent throughout the nation, and currently there are limited efforts to directly influence these programs. In areas with a strong wind industry (including manufacturing and project development), the implementation of high school vocational training for this field in collaboration with community colleges may be appropriate and may provide a strong feeder program for the industry. This activity would initiate a pilot wind energy vocational program working with interested vocational programs and community colleges. If successful, the program could be implemented on a wider basis.

Development Needs of Community College, Vocational, and Direct Organizational Training Centers

The development of programs at the community college, vocational, and direct organizational technical centers would support a vast majority of the individuals who will join the wind industry. As described, in many cases this focuses on people with technical skills, but the ability of these programs to train people with other skills, such as accounting and project management, should not be overlooked. Specific activities to help support this sector include:

- *Standardize curricula development.* Working with the DOL and Department of Education, industry, universities, and community colleges, standardized curricula should be developed for use at community college and vocational levels. Although most community college faculty indicate that they can develop much of their own curricula for technical training programs, the development of a certification standard and the creation of a more general and basic wind curricula may be helpful. Additionally, short courses to allow detailed training in specific areas that could be provided individually as part of worker re-training or continuing education programs or combined into a full introductory wind class at a higher level would be useful. Funding could cover the creation of curricula, curricula standards, and implementation of short courses.
- *Develop secondary and non-traditional vocational training programs.* Actively engage in secondary and non-traditional vocational programs with a potential focus on ex-military and

auto workers. Based on initial pilot activities, the program could be implemented on a wider basis. This activity would provide near-term and high-impact vocational training programs for the wind industry, providing entry-level workers to support the recovery or to spur interest in expanded community college or university training.

- *Create and support a community college Web portal.* Although initially implemented by AWEA and other organizations, a single-stop portal should be developed to identify training programs for individuals interested in entering the wind industry or expanding their understanding of wind technologies. Such a portal would provide accurate data on community college or similar programs, their offerings, and potentially up-to-date schedules. This could include information on all relevant classes, including 1- or 2-year programs and short courses. Once initiated, such a portal could rely on organizations providing this information for new or existing programs, but until the site is institutionalized, a serious effort would be required to identify and then collect the appropriate data.
- *Support green job infrastructure development.* Through competitive grants and collaboration with industry, support the needed infrastructure to provide hands-on, wind-related training at multiple levels. This would likely include collaboration with private or public organizations and the wind industry to institute multiple technical training centers in conjunction with wind farms, community colleges, universities, and laboratories where individuals could obtain hands-on training in wind turbine operation and maintenance. This activity would target training for both large and distributed wind technologies and deployment programs such as small-wind installer training. The cost of modern wind equipment, including wind turbines and towers, designed for educational and vocational applications is excessive (reportedly up to $5 million to initiate a new community college program). This high facilities cost and the access to equipment make it difficult for community college programs to ramp up to meet current and future industry needs. Federal funds would act as seed funding to leverage state, private sector, and other funding to attract new staff and obtain required equipment.
- *Develop instruction expertise.* Even with the investment in facilities to support training programs, without the development of educational personnel, teachers, and professors to introduce students to this new technology, there will not be much impact. Already the availability of trained personnel who can act as instructors is very limited. Additionally, wages at community colleges typically cannot compete with industry and, in many cases, the starting salary for a wind technician is higher than the standard pay for many professors. The problem is further complicated by rapid change in the wind industry, forcing faculty to obtain continuing education, while no such opportunity really exists. To help support this considerable mismatch, several activities are required, including the development of continuing education sessions, professional internships, and educational grants for professors at community colleges or other educational centers focused on wind technologies. Additionally, the development of exchange programs, expert video series, and executive loan programs should be implemented at the state, regional, and national levels to encourage wind experts to assist in the education of people entering the wind market. In many cases, there is strong industry interest to support such endeavors, but a facilitation plan must be developed and implemented.
- *Support cross-fertilization of institutional experience.* Through the AWEA Education Working Group, community colleges are interacting and sharing information about approaches and challenges. This cross-fertilization is critical to developing training standards and to supporting uniformity across the educational system. AWEA is currently working to support this endeavor, but its activities are critical to increasing the size and scale of wind educational programs,

especially in the community college sector.

Development Needs of Higher Education

Many of the skills required for the successful long-term development of the wind industry, from engineering to transportation management, will require individuals with advanced degrees. Additionally, the requirement to lower the cost of wind systems will require expanded research and deployment innovation, activities that will be driven for the most part by individuals with advanced degrees. The following activities are identified to support the development of an infrastructure to support these needs:

- *Identify skills required to expand the wind industry.* As described previously, little is known about the job skills that will be required from the wind industry over the next 20 years. Even in areas where specific skills are known to be required, such as power engineering, the exact number of skilled persons that will be needed and the level of re-training required to attract people with relevant technical experience from outside the industry are largely unknown. Unlike at community colleges (which are adept at making rapid changes to support changing educational needs), universities may take many years to institutionalize new programs or educational pathways, and these are unlikely to be developed unless need and long-term applicability can be demonstrated. For these reasons, a process should be implemented to better understand and document the higher-education training needs of the wind industry now and in the future.
- *Support a national information clearinghouse for university programs.* A great deal of activity is ongoing in the university sector focused on wind energy technology and its application. University activities are also broad, from individual professors working on research projects, to defined wind application centers, to graduate programs providing advanced engineering degrees with specializations in wind energy technology. Additionally, DOE, industry, and other organizations are implementing funding mechanisms to support curricula, research, and program development. As the industry expands and includes experts from non-engineering fields, the issues of tracking all of the programs expand exponentially. This can lead to confusion regarding program development and focus, making it difficult for the wind industry and students interested in obtaining degrees to determine which organizations are most applicable to their needs. The creation of a national database or guide that provides information on university programs, their activities, and key research or educational staff would greatly enhance industry-to-institution collaboration (and also institution-to-institution collaboration). AWEA is in the process of implementing such a portal; however, that organization is stretched for resources, and it is not clear if it can provide the level of engagement and upkeep that will be required to make such a portal successful.
- *Expand Wind for Schools and other program development activities.* The Wind for Schools model promotes developing university programs focused on wind deployment and supported through the implementation of university-level wind curricula and installing (with associated curricula and support) small wind turbines at K-12 schools. The Wind for Schools model is designed to provide short-term funding and technical support to help university programs (called Wind Application Centers), allowing them to become established and self-sustaining. It is currently implemented in 11 states. Since one of the goals of this activity is the development of the centers into robust, state-based, wind-focused educational centers, it actually supports viable educational programs at universities and 4-year colleges. This funding also allows and supports the development and implementation of wind curricula at the university, expanding the educational infrastructure while allowing hands-on implementation experience through the

installation of small wind turbines at K-12 host schools. This is different from most other research and curricula development programs in that one of the goals is the establishment of a center, which is designed to have lasting impact while planting the seed within the university to develop formal degree programs in wind technology. Expansion of this or similar programs should be undertaken to start the development of an expanded university-level educational system, including a deployment focus.

- *Support industry green workforce integration.* The wind industry has a vested interest in developing an educated workforce but also leveraging the potential research possibilities at universities to improve wind energy systems. Following the development of a clearinghouse detailing existing university programs, efforts must be made to reach out to wind companies interested in providing internships, scholarships, fellowships, postdoctoral appointments, endowed professorships, and research. This activity would provide coordination between university programs and private industry to expand collaboration and improve systematic support. The NSF is in the process of developing a university/industry wind incubator, but opportunities exist for others focusing in different areas of the wind space.
- *Launch national wind competitions.* Modeled on the Solar Decathlon, the Solar Car competition, and other international technology competitions such as the Formula SAE for universities and the European Wind Car competition, a wind energy competition for universities and colleges should be implemented. Such a challenge has been very effective at leveraging the enthusiasm of university students, leading to jobs in that technology area. The nature of the competition would need to be defined but could include a design-based improvement process, leading to research projects or another national wind event.
- *Develop a university collaboratory (or consortium).* Develop a university-based research, development, and deployment consortium on wind technologies. This organization would work to reduce programmatic overlap with existing and new university-based wind energy programs and allow the development of technology-wide, cross-university curricula, degree programs, and educational networks that would include ties to international wind research leaders such as Risoe National Laboratories, TU Delft, University of Stuttgart, and Institut für Solare Energieversorgungstechnik (Fraunhofer Institute for Wind Energy and Energy Systems Technology). Curricula and research funding would then be directed toward specific consortium members (based on programmatic need) and would give the wind industry a clear path to invest in expanded university-based research and education development. The consortium could be modeled after the Network for Earthquake Engineering (http://www.nees.org/), which coordinates research and education in this area through a broad, primarily university-based, advanced multi-sector network. As described, the NSF is in the process of developing a wind/industry incubator that could grow into such an organization, but steps could be taken in the near term to implement such a collaboratory, greatly reducing the fragmentation and institutional overlap in the wind sector for institutions of higher education.

Continued Collaboration and Development

The U.S. DOE will continue to develop this roadmap effort. In addition to continued work with the AWEA Education Working Group and other organizations, meetings will be held to comment and expand on this document. Comments from all sectors, including general public comments, are encouraged and should be directed to:

E. Ian Baring-Gould
Senior Engineer & Supervisor for Wind Technology Deployment
Deployment & Industrial Partnerships
National Wind Technology Center
National Renewable Energy Laboratory - MS3811
1617 Cole Blvd.
Golden, Colorado 80401-3393 USA
303-384-7021
ian.baring-gould@nrel.gov

Michele DesAutels
Wind and Hydropower Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Forrestal Building, EE2B-5H088
1000 Independence Ave., SW
Washington, DC 20585 USA
202-586-0815
michele.desautels@ee.doe.gov

Appendix A: Wind Education Stakeholders

The following is an incomplete list of institutions with interest in wind energy workforce development.

Wind Application Centers (deployment-focused programs with some applicable research component)

- Appalachian State University, NC (North Carolina Wind Energy Center)
  http://www.wind.appstate.edu/
- Boise State University, ID (power electronics, mechanical engineering focus)
  http://www.boisestate.edu/
- Colorado State University (wind deployment, atmospheric science, engineering disciplines, law, business)
  https://sites.google.com/a/rams.colostate.edu/csu-wac/home
- James Madison University, VA (Center for Energy and Environmental Sustainability)
  http://www.cisat.jmu.edu/cees/
- Kansas State University (power systems engineering)
  http://www.k-state.edu/
- Northern Arizona University – Department of Mechanical Engineering
  http://cefns.nau.edu/Academic/ME/ or http://www.wind.nau.edu/
- Montana State University (mechanical and industrial engineering)
  http://www.montana.edu/wwwprov/
- Penn State University, PA (Institute of Energy and the Environment)
  http://www.psiee.psu.edu/windenergy/
- South Dakota State University
  http://www3.sdstate.edu/
- University of Alaska – Fairbanks (Alaska Center for Energy and Power, Wind-Diesel Applications Center)
  http://www.uaf.edu/acep/alaska-wind-diesel-applic/
- University of Nebraska – Lincoln (Nebraska Center for Energy Science Research, electrical engineering, system integration)
  http://www.unl.edu/

Universities (defined wind energy programs)

- University of Massachusetts – Renewable Energy Research Laboratory (general wind turbine technology curriculum and model for basic entry-level engineering program, wind resource assessment)
  http://www.ceere.org/rerl/
- University of Colorado – Boulder (Renewable and Sustainable Energy Institute - atmospheric science, engineering disciplines, law, business)
  http://rasei.colorado.edu/index.php?id=1&page=Home
- Colorado School of Mines (atmospheric science, controls, management)
  http://engineering.mines.edu/research/sensing-comm-control/project/?pid=55
- Texas Tech (wind engineering and met tower test station)
  http://www.wind.ttu.edu/
- New Mexico State University (Southwest Technology Development Institute)
  http://www.nmsu.edu/~tdi/
- University of Wyoming (Wind Energy Research Center - aerodynamics, controls)
  http://www.uwyo.edu/werc/

- University of Maryland (unsteady aerodynamics)
  http://umerc.umd.edu/projects/wind/index.html
- University of Maine (full-scale structural testing and offshore testing, awarded DOE University Consortia research grant)
  http://www.aewc.umaine.edu/
- North Carolina State University (NC Solar Center)
  http://www.ncsc.ncsu.edu/energy_primer/wind_energy.cfm
- University of Iowa (wind power management)
  http://www.mie.engineering.uiowa.edu/IEProgram/WindPowerManagement.php
- University of Delaware (offshore wind technologies)
  http://www.ceoe.udel.edu/windpower/index.html
- Saint Francis University (Renewable Energy Center)
  http://www.francis.edu/REC.htm
- University of California – Davis (California Wind Energy Collaborative)
  http://cwec.ucdavis.edu/
- University of Houston (Wind Energy Center)
  http://www.egr.uh.edu/wind/
- University of Hawaii (Hawaii National Marine Renewable Energy Center)
  http://hinmrec.hnei.hawaii.edu/
- University of Wisconsin – Madison (College of Engineering, Vestas partnership, DOE grant)
  http://www.engr.wisc.edu/
- Iowa State University (DOE American Manufacturing Initiative, Iowa Energy Center)
  http://www.energy.iastate.edu/renewable/wind/wem-index.htm
- Massachusetts Maritime Academy (have wind turbine, initiating a wind program)
  http://www.maritime.edu/
- University of Minnesota (awarded DOE University Consortia research grant)
  http://www.umorepark.umn.edu/WindEnergyResearchConsortium.html
- Illinois Institute of Technology (Wanger Institute for Sustainable Energy Research - Awarded DOE university consortia research grant)
  http://www.iit.edu/wiser/

Other undefined educational wind energy programs (from AWEA education Web site and other sources)

- Clarion University, PA (electric utility technology)
  http://www.attecolleges.org/
- Georgia Institute of Technology (Strategic Energy Institute)
  http://www.energy.gatech.edu/
- University of Arkansas (Supply Chain Management Research Center)
  http://scmr.uark.edu/
- University of Colorado – Denver (Global Energy Management MBA degree)
  http://business.cudenver.edu/Graduate/GEM.htm
- University of Texas at Austin (law program)
  http://www.utcle.org
- University of Wisconsin – Madison (business focus)
  http://epdweb.engr.wisc.edu/
- Utah State University

http://www.usu.edu/
- Washington State University
  http://www.wsu.edu/
- West Virginia University
  http://dev-www1.wvm.edu/
- Massachusetts Institute of Technology (floating offshore platforms)
  http://web.mit.edu/
- Cornell University (renewable energy)
  http://www.sustainablefuture.cornell.edu/research/energy.php
- Illinois State University (Department of Technology - Renewable Energy)
  http://tec.illinoisstate.edu/renewable_energy
- Oklahoma State University
  http://www.osuokc.edu/home/
- University of North Dakota
  http://www.undeerc.org/

University-industry consortia

- Center for Research and Education in Wind (CREW), CO
  http://www.coloradocollaboratory.org/
- Lone Star Wind Alliance, TX
  http://www.egr.uh.edu/wind/lswa/
- Massachusetts Technology Collaborative
  http://www.masstech.org/
- Iowa Alliance for Wind Innovation and Novel Development
  http://www.iawind.org/
- European Academy of Wind Energy
  http://www.eawe.eu/

Community colleges/wind tech programs (program focus has not been identified)

- Cape Cod Community College, MA
  http://www.capecod.edu/web/guest/home
- Clinton Community College, NY
  http://www.clinton.edu/mathscience/windenergyturbinetech.cxml
- Cloud County Community College, KS
  http://www.cloud.edu/
- Cerro Coso Community College, CA
  http://academic.cerrocoso.edu/industrial/wind/index.htm
- Columbia Gorge Community College, OR
  http://www.cgcc.cc.or.us/
- Columbia College, IL
  http://www.colum.edu/
- Cuyahoga Community College, OH
  http://www.tri-c.edu/Pages/default.aspx
- Crowder College, MO
  http://www.crowder.edu/
- Delta College, MI

http://www.delta.edu/

- Frostburg State University – Wind and Solar Energy Certification Program
  http://faculty.frostburg.edu/engn/soysal/Activities/Training.html
- Grinnell College, IA
  http://www.grinnell.edu/
- Iowa Lakes Community College, IA
  http://www.iowalakes.edu/
- Ivy Tech Community College, IL
  http://www.ivytech.edu/
- Holland College, PEI – Canada
  http://www.hollandcollege.com/
- Kalamazoo Valley Community College, MI
  http://windenergycenter.kvcc.edu/tech_training.htm
- Lake Region State College, ND
  http://www.lrsc.edu/
- Lakeshore Technical College, WI
  http://www.gotoltc.com/
- Lansing Community College, MI
  http://www.lcc.edu/home/future_students/
- Laramie County Community College, WY
  http://www.lccc.cc.wy.us/
- Laredo Community College – Economic Development Center, TX
  http://www.laredo.edu/
- Lakeshore Technical College, WI
  http://www.gotoltc.com/
- Mesa Lands Community College, NM
  http://www.mesalands.edu/wind/
- Minnesota West Community and Technical College
  http://www.mnwest.edu
- Northeastern Junior College, CO
  http://www.njc.edu/programs/ct_windenergy_aas.html
- Oklahoma State University – Oklahoma City
  http://www.osuokc.edu/wind
- Sauk Valley Community College, IL
  http://www.svcc.edu/
- Texas State Technical College West Texas
  http://www.westtexas.tstc.edu/index.cfm?Action=Programs&division_id=19&dept_id=37&short_dept_name=wet
- Turtle Mountain Community College, ND
  http://www.turtle-mountain.cc.nd.us/
- West Valley College – Advanced Transportation Technology & Energy, CA
  http://dev-www1.wvm.edu/

Vocational or technical campuses

- Advanced Transportation Technology & Energy, CA
  http://www.attecolleges.org/
- Environmental Training Center, CA
  http://www.rebrac.org/
- High Plains Technology Center, OK
  http://www.hptc.net/bis/wind/wind.asp
- Lakeshore Technical College, WI
  http://www.gotoltc.com/
- Michigan Institute of Aviation and Technology
- Mitchell Technical Institute, SD
  http://www.mitchelltech.com/
- Wayne Technical and Career Center, NY
  http://wflboces.org/departments.cfm?subpage=170

Educational support

- American Wind Energy Association, Education Working Group, Scholarship Fund
  http://www.awea.org/education/
- National Renewable Energy Laboratory, Wind School Programs
  http://www.windpoweringamerica.gov/schools.asp
- U.S. Department of Energy
  http://www.energy.gov/foreducators.htm

Other organizations that provide education, including continuing professional education and workshops

- Great Plains Economic Development Center, OK
  http://www.gptech.org/edc2k/default.htm
- Institute of Electrical and Electronics Engineers (IEEE)
- Interstate Renewable Energy Council (IREC)
- Utility Wind Integration Group (UWIG)
- American Wind Energy Association (AWEA)
- European Wind Energy Association (EWEA)

K-12 educational programs / curricula

- KidWind
  http://www.kidwind.org
- The Need Project
  http://www.need.org/
- WindWise Education
  http://www.windwiseeducation.org/
- Wind for Educations
  http://www.energyforeducators.org/
- Wind for Schools
  http://www.windpoweringamerica.gov/schools_wfs_project.asp

Research organizations

- National Renewable Energy Laboratory, CO
  http://www.windpoweringamerica.gov
- Sandia National Laboratory, NM
  http://sandia.gov/wind
- Idaho National Laboratory
  https://inlportal.inl.gov/portal/server.pt/community/renewable_energy_home/419
- Desert Research Institute, NV
  http://www.dri.edu/
- USDA – Agricultural Research Service, TX
  http://ars.usda.gov/Main/site_main.htm?modecode=62-09-05-15
- Wind Energy Institute of Canada, PEI – Canada
  http://www.weican.ca/

Related constituencies

- U.S. Department of Labor
- U.S. Department of Education
- State education and workforce development offices
- State and local economic development players

Appendix B: Workforce Development Activities

Many efforts are currently underway to support and expand workforce development options and provide a better understanding of the wind industry's workforce development needs.

The following activities are ongoing:

The American Wind Energy Association (AWEA) educational program data clearinghouse/database: AWEA is developing a database of existing wind energy educational programs.

AWEA industry and educational survey on workforce needs: Conducted in 2008 and 2009, this survey offers the first comprehensive look at industry workforce needs and the educational infrastructure to support the development of these new workers.

AWEA wind technician skills identification/certification: This effort provides basic skills identification and credentialing for wind technician positions, focusing on the minimum skill requirements for these positions.

AWEA Education Working Group: This coordination activity supports wind education collaboration, including subgroups focusing on K-12, community college, and university sectors. Collaboration is strongly weighted toward community colleges as this is the primary focus of AWEA's industry members.

DOL green jobs programs: Under the direction of the DOL, several grants have been announced focusing on job creation in the energy efficiency and renewable energy sector. Grants include the nearly $190 million State Energy Sector Partnership and Training Grants, the $150 million Pathways Out of Poverty grants, the $100 million Energy Training Partnership Grants, and $55 million in green training grants. Most of this program funding was authorized by the American Recovery and Reinvestment Act of 2009. These activities provide funding for a wide range of programs to support job training and education to help teach dislocated and disadvantaged workers the skills required in emerging industries, including energy efficiency and renewable energy. Although some information is available on these grant recipients, it is unclear how many support efforts in the wind sector.

Federal collaboration: DOE, DOL, U.S. Department of Education memorandum of understanding on energy and workforce development.

Workforce requirements: In a collaboration between NREL and AWEA, with the support of DOE's Wind and Water Power Program, staff members are documenting the workforce need outlined in the *20% Wind Energy by 2030* report, as well as the deployment of large amounts of wind technologies. These efforts are underway to understand the economic impacts of wind development, from component manufacturing through final turbine installation.

Wind for Schools project: The general approach of this DOE-funded project is to implement Wind Energy Application Centers (WACs) at state-based universities or colleges. As part of the wind energy curriculum, college students assist with developing, permitting, and installing small wind turbines at primary and secondary schools. The wind turbine is purchased through state funding and is implemented with age-appropriate educational curricula and teacher instruction at the K-12 schools. The wind turbine located at the school provides students, teachers, and community members with a physical example of how communities can take part in providing for the economic and environmental security of the nation

while allowing exciting, hands-on educational opportunities for the students. Universities and K-12 schools are linked through several Web services, including logging turbine data that are used to expand the educational opportunities. Each WAC is expected to have university-level classes incorporating wind applications and to install approximately five project turbines each year. Additional activities associated with workforce development include supporting development of an educational workforce roadmap for the U.S. industry. This program is currently active in 11 states implemented in two phases: Alaska, Arizona, Colorado, Idaho, Kansas, Nebraska, North Carolina, Montana, Pennsylvania, South Dakota, and Virginia.

DOE Wind Program Educational Grants: In the summer of 2009, DOE announced awards to 13 educational workforce development projects as part of a competitive Funding Opportunity Announcement (FOA) focused on removing barriers to achieving 20% wind energy by 2030. The funding covers education and training activities at 2-year technical colleges, 4-year colleges and universities with undergraduate and graduate programs, and support to organizations providing continuing education. The funding provided for these activities exceeded $3.4 million over 2 years and is being implemented in nine states.

Curricula development at the K-12 level: Several organizations are directly involved in the expanded development of curricula at the primary and secondary levels, including the NEED Project, KidWind, and the new WindWise curricula primarily focused at secondary school audiences. The KidWind project is also very involved in expanding educational opportunities through the Wind KidWind Challenge and WindSenator programs, which involve wind educators and students in hands-on activities associated with wind technologies.

DOE Energy Educational Programs: DOE has several internship programs, primarily focused at K-12 teachers, community colleges, and university student internship programs. These programs provide seasonal internship opportunities for teachers and students, primarily at DOE or National Laboratories.